RECENT DEVELOPMENTS ON THE SMALL GASIFIER

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During the years prior to World War II, thousands of gas producers of the Wellman-Galusha type were utilized in the United States to convert coal to low BTU gas. These so called "small gasifiers" produced gas for all types of utility and industrial applications.

After World War II, the gas transmission system was expanded bringing low cost natural gas to eastern markets. The small gasifier could no longer compete and these installations were closed until only three still operate.

The energy bill presently being worked on by Congress includes provisions to deregulate the price of natural gas. It therefore appears that the small gasifier may once again become competitive and could provide a substantial volume of industrial fuel gas for use by American industry.

In the spring of 1976, DOE initiated a program to demonstrate the utilization of low BTU gas in industrial applications. A total of six (6) projects were undertaken with partial funding by the Federal Government. Four commercially available small gasifiers are being utilized:

1.	The Wellman-Galusha	Three (3) Projects
2.	The STOIC	One (1) Project
3.	The Wellman-Incandescent	One (1) Project
4.	The IGI	One (1) Project

The coals include anthracite as well as bituminous from Wyoming, Utah and Eastern Kentucky. The applications are:

1. Fuel for brick kilns.
2. Boiler feed for space heating of campus buildings.
3. Boiler feed for heating and cooling of housing, shopping centers, schools, industrial park, etc.
4. Boiler feed for process steam and spray drying of milk whey.
5. Fuel for tunnel kilns and dryers.
6. Fuel for an industrial park.

The range of gas clean-up for these projects is:

1. Hot raw gas (no treatment after leaving gasifier).
2. Gas that has tar and particulates removed.
3. Gas with complete clean-up including desulfurization.

In addition to these federally funded projects several privately funded commercial projects have gotten underway.

Let's take a detailed look at the "small gasifier":

Figure 1 shows the Wellman-Galusha gasifier.

In addition to the types mentioned above, other small gasifiers include Wilputte and Riley Morgan.

This equipment is a self-contained unit and requires no investment for a boiler plant when producing low BTU gas. Adequate provision for steam for gas making is included in the engineering design of the plant. Ample fuel and ash storage bins are provided as an integral part of the unit. This fixed bed gasifier operates at atmospheric pressure.

A two compartment fuel bin forms the top of the machine. The upper section is a storage bin and is usually filled by a bucket elevator. The lower compartment is separated from the upper compartment by disc valves through which fuel is fed as required. Similar valves cover the entrance of each of the

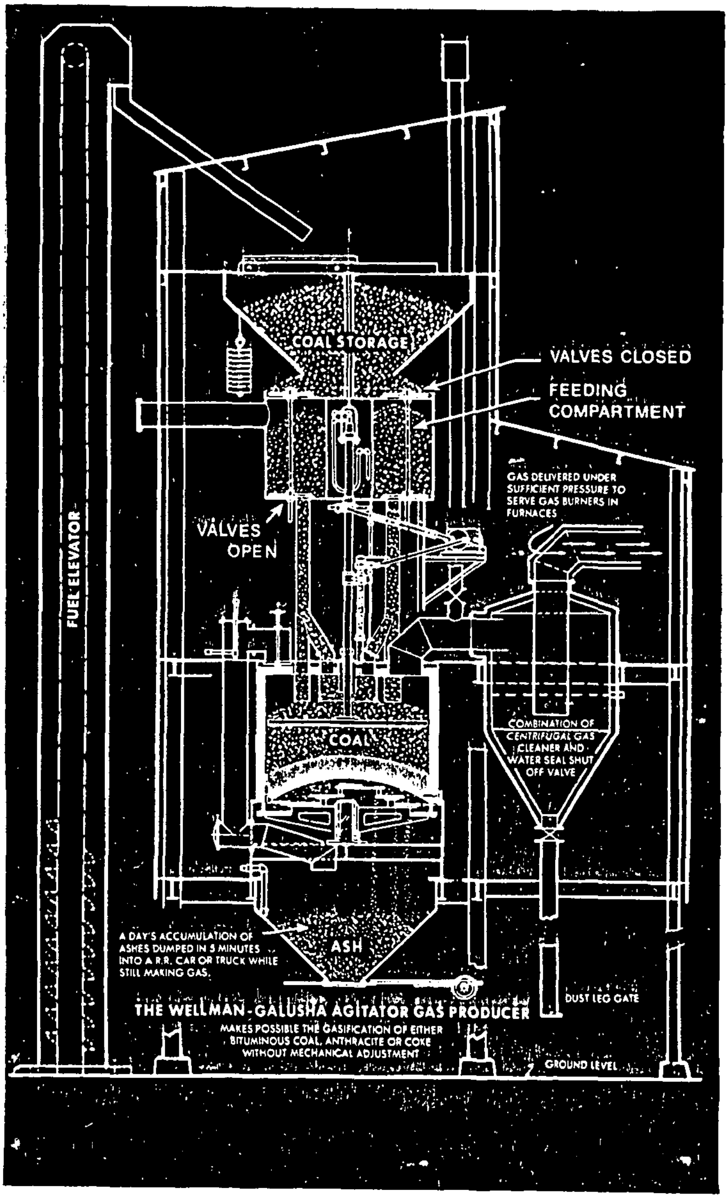

FIGURE 1. *Wellman-Galusha Agitator Type Gas Producer*

heavy steel pipes connecting the lower bin to the fire chamber. Fuel from the lower bin flows continously through these feed pipes to fill the fire chamber.

Fuel feed pipe valves are normally open, but for brief intervals they are closed, during which time the upper valves in the lower compartment are open in order to fill the feeding compartment with fuel. A simple interlocking mechanism prevents the opening of the upper valves unless all lower valves are tightly closed. It also prevents opening any lower valves while any top valve is open. This prevents the escape of gas from the gas making chamber through the coal compartments to the atmosphere.

The gas making chamber is completely water jacketed. Waste heat in the water jacket generates steam required for making gas. Steam and air are introduced at the bottom of the bed. The bed is supported by revolving grates through which dry ash is continously ejected to the ash hopper.

A slowly revolving water cooled horizontal arm, which also spirals vertically below the surface of the fuel bed, retards channeling and maintains a uniform fuel bed. This facilitates the production of uniform quality gas.

Raw gas containing particulates, tars, oils, hydrogen sulfide, etc., leaves the gasifier at a temperature of between 800^{o}F and 1250^{o}F.

These small gasifiers are designed to produce either low BTU gas or intermediate BTU gas. Low BTU gas has a heating value of approximately 150 BTU/SCF and is produced by using air in the gasifier. Intermediate BTU gas has a heating value of approximately 300 BTU/SCF and is produced by using oxygen in the gasifier. For comparison purposes, natural gas of pipeline quality has a heating value of approximately 1000 BTU/SCF.

Figure 2 is a simplified flow diagram showing the various processing steps in the manufacture of clean gas from receipt of coal through sulfur removal.

Table 1 summarizes the capital costs and operating costs of small gasifier systems. There are sixteen (16) cases considered: 1A, 1B, 1C and 1D; 2A, 2B, 2C and 2D; 5A, 5B, 5C and 5D; 10A, 10B, 10C and 10D. The numbers indicate the number of gasifiers in the plant - one, two, five or ten. The letters A, B, C and D refer to the type of gas produced and the type and cost of coal used. Cases A and B are air-blown gasifiers which produce low BTU gas - about 150 BTU per cu. ft. Cases C and D are oxygen-blown gasifiers which produce medium BTU gas - about 300 BTU per cu. ft. In cases A and C high sulfur coal at $25 per ton is utilized while in cases B and D low sulfur coal at $35 per ton is used.

The second line of Table 1 shows the Coal Feed to the system in tons per day of sized coal (2" x 1-1/4"). Several things should be noted: the effect of modules and the effect of the use of oxygen. The coal usage in the 2, 5, and 10 gasifier cases is 2, 5 and 10 times that of the comparable single gasifier cases. When oxygen is used instead of air, the coal feed (and resultant BTU conversion) is substantially increased - 132 tons per day versus 78 tons per day for the single gasifier cases.

The information relevant to Gas Production is shown on the next three lines of the Table: millions of standard cubic feet per day produced; the heating value of the gases produced (158 BTU per cu. ft. air-blown and 285 BTU per cu. ft. for oxygen-blown); and the total BTU produced in billions per day.

You will note that almost 40% more BTU are produced for a given number of gasifiers by using oxygen instead of air.

The next line shows the land area required. These land requirements are based on storing 30 days coal supply.

The line "Total Plant Investment" in current dollars, includes coal storage and handling, gasification, particulate removal, tar removal, ash disposal, and waste water treatment and disposal.

For Cases A and C (High Sulfur Coal), sulfur removal facilities are also included. Cases C and D (Oxygen-blown Gasifier), oxygen plants are required. In all cases, Total Plant Investment includes an Administration and Maintenance

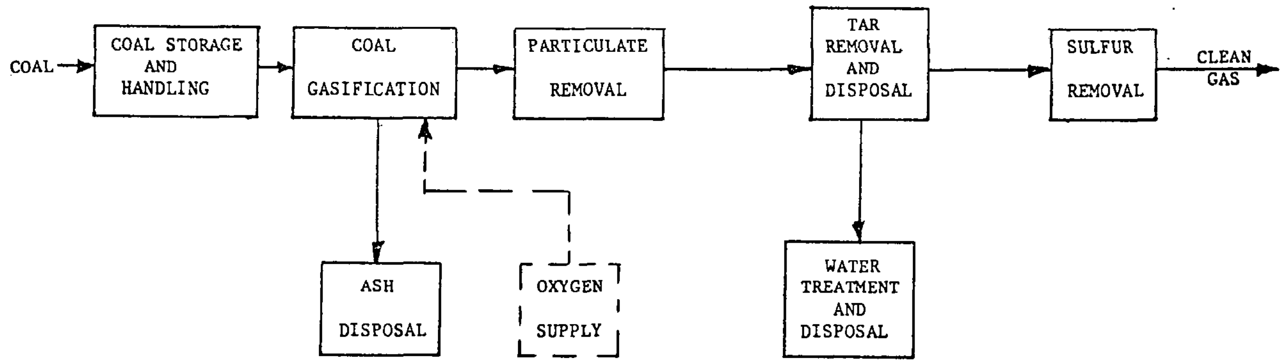

FIG. 2 COAL GASIFICATION (LOW AND INTERMEDIATE BTU GAS)

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TABLE 1

SMALL GASIFIERS COST INFORMATION

CASE	1A	1B	1C	1D	2A	2B	2C	2D	5A	5B	5C	5D	10A	10B	10C	10D
GASIFIER (10' Dia.) Qty.	1	1	1	1	2	2	2	2	5	5	5	5	10	10	10	10
COAL FEED (2" x 1 1/4") T/Day	78	78	132	132	156	156	264	264	390	390	660	660	780	780	1320	1320
GAS PRODUCTION																
SCF/DAY (DRY) MM	10.09	10.38	7.84	7.96	20.46	20.76	15.67	15.93	50.44	51.9	39.20	39.8	100.88	103.8	78.41	79.6
HEATING VALUE (DRY BTU/SCF	158	158	285	285	158	158	285	285	158	158	285	285	158	158	285	285
BTU/Day x 10^9	1.59	1.64	2.23	2.27	3.23	3.28	4.47	4.54	7.97	8.2	11.17	11.35	15.94	16.4	22.35	22.7
AREA REQUIRED ACRES	3.2	2.8	3.6	3.3	3.2	2.8	3.6	3.3	6.0	5.5	6.6	6.1	7.4	6.5	8.9	8.0
TOTAL PLANT INVESTMENT MM$	4.77	3.07	7.92	5.73	7.02	4.63	12.39	9.53	11.89	8.62	22.35	18.22	18.28	13.92	36.92	31.47
ADJUSTED PLANT INVESTMENT MM$	4.06	2.24	6.81	4.63	5.99	3.66	10.80	7.98	9.84	6.58	18.72	14.62	15.00	10.68	30.98	25.56
EST. GAS COST (PRICES)																
(1) Total Investment, Utility Financing	4.09	3.62	5.35	5.11	3.18	3.15	4.61	4.67	2.66	2.75	3.97	4.23	2.37	2.57	3.70	4.04
(2) Adjusted Plant Investment ** Utility Financing	3.93	3.45	5.17	4.93	3.07	3.04	4.44	4.55	2.56	2.66	3.85	4.11	2.29	2.50	3.59	3.94
(3) Total Investment 100% Equity 20 Yr. Depreciation No Profit	3.35	3.14	4.45	4.44	2.63	2.77	3.86	4.11	2.27	2.46	3.44	3.78	2.06	2.32	3.25	3.64
(4) Adjusted Plant Investment ** 100% Equity 20 Yr. Depreciation No Profit	3.28	3.06	4.37	4.37	2.58	2.72	3.80	4.06	2.23	2.42	3.39	3.73	2.03	2.29	3.21	3.60

BASIS
Case A - High (3%) Sulfur Coal @ $25/ton with Air-Blown Gasifier
Case B - Low (0.7%) Sulfur Coal @ $35/ton with Air-Blown Gasifier
Case C - High (3%) Sulfur Coal @ $25/ton with Oxygen-Blown Gasifier
Case D - Low (0.7%) Sulfur Coal @ $35/ton with Oxygen-Blown Gasifier

**Administration Building and Waste Water Treatment Facilities Deleted

Building, but excludes land costs. For all cases, it is assumed that needed utilities will be purchased. Therefore, no capital costs are included for cooling water, steam generation and compressed air facilities.

It is expected that Small Gasifier Facilities will be generally located near an existing industrial facility. Therefore, in many cases waste water treatment facilities will exist as well as suitable office space for administration and maintenance facilities. The line Adjusted Plant Investment reflects the deletion of these items from Total Plant Investment.

The last group of numbers, Estimated Gas Costs, are most significant to anyone considering building a coal gasification facility. They have been calculated on four different bases. The first line, (1), results from use of the Utility Financing Method as outlined in ERDA's Gas Cost Guidelines. The costs stated are average gas costs and entail use of the following parameters:

1. 20-year project life.
2. 20-year straight-line depreciation on plant investment, allowance for funds used during construction and capitalized portion of start-up costs.
3. Debt-equity ratio of 75/25.
4. Percent interest on debt of 9 percent.
5. Percent return on equity of 15 percent after taxes.
6. Federal income tax rate of 48 percent.

ERDA maintenance costs are proportional to the plant section investment

1. 6 percent for coal feed preparation, coal gasification, gas quench and solids removal.
2. 3 percent for sulfur recovery, product gas compression and drying, oxygen plant, liquid and solid effluent treating and water treating.
3. 1 percent for all other offsites.

We used 3 percent of total plant investment as a simplification.

Included in the total capital requirements are:

1. Estimated installed cost of both onsite and offsite facilities.
2. Project contingency at 15 percent of the estimated cost of the facilities.
3. Initial charge of catalyst and chemicals.
4. Paid-up royalties.
5. Allowance for funds used during construction.
6. Start-up costs.
7. Working capital.

Operating costs are based on a 90 percent plant service factor. Included in operating costs are:

1. Purchased utilities.
2. Raw materials
3. Catalysts and chemicals.
4. Purchased water.
5. Labor.
6. Administration.
7. Supplies.
8. Local taxes and insurance.
9. Ash disposal.

No credit is taken for byproducts such as sulfur, tars, oils, etc. As stated above, it is assumed that power, steam and water will be purchased. The cost of power is 2.7¢ per KW hour. Steam cost is assumed to be $3.14 per 1000 pounds. Cooling water is 3.8¢ per 1000 gallons and make-up water 40¢ per 1000 gallons.

The gas costs resulting from these calculations range from $2.37 per million BTU for the 10 air-blown gasifier system to $5.35 for the single oxygen blown gasifier system. These gas costs are based on the Utility Financing Method and are slightly different from the costs which result from incorporating commercial financing considerations and private investor return requirements.

The same parameters and method of calculation were used to determine the gas costs shown on the next line, (2), Adjusted Plant Investment, Utility Financing. As indicated above, the Adjusted Investment refers to the deletion of the Administration Building and Waste Water Treatment Facilities from the Gasifier System. Costs for comparable cases are slightly reduced as expected.

Providing 100% equity with zero return on investment results in substantially lower gas cost as shown on line (3) - the range of costs is from \$2.06 per million BTU to \$4.45 per million BTU.

With adjusted investment, these gas costs are reduced even further as shown on line (4).

Some general conclusions can be drawn from the gas cost calculations:

1. The larger the plant, the lower the cost of the gas produced.
2. The cost of 150 BTU gas is less than the cost of 300 BTU gas.
3. The cost of producing gas by this small gasifier system is lower than any other known technology. This has been substantiated by studies performed by Dravo on facilities up to approximately 25 billion BTU per day. Indications are that the small gasifier is competitive for facilities of considerably higher capacities.

All of the costs discussed so far have been applied to the battery limits of the gasifier facility.

When an existing plant is converted from use of natural gas to either 300 BTU gas or 150 BTU gas changes must be considered in burners, fuel gas piping, instruments, flue gas piping, compressors, forced and induced draft fans, exhaust stocks, etc. This is necessitated by the changes in fuel gas volume, flue gas volume and flame temperatures.

Special precautions must be taken with respect to the toxicity of the gas produced. Both 150 BTU gas and 300 BTU gas contain large percentages of carbon monoxide which is colorless and odorless. The toxic effects of this gas depend on the concentration level and time of exposure. The distribution system, therefore, should include valving and alarms as well as the use of an odorant.

The feasibility study for a given application should include not only the costs of producing the fuel gas, but also the costs of adapting the existing plant to its use. The small gasifier should not be considered the answer to every coal gasification problem. As the size of the facility increases other processes such as Lurgi, Koppers-Totzek and Babcock and Wilcox must be considered. When second generation technology has been proven those processes also must be considered.

At the present time, however, the small gasifier is a realistic answer for many industrial plants. The distribution and retrofit costs and the applications of the gas along with the battery limits costs will determine whether the gas produced should be 150 BTU or 300 BTU. The degree of "clean-up" of this gas will depend upon environmental regulations, process requirements and the coal used.